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Tetsuo Kimoto*

*Okayama University,

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**Abstract**

In the spleen of patient exposed to atomic bomb as well as in the infective spleen and leukemic spleen sometimes characteristic endothelium of the trabecular vein can be observed and this canalicula in the trabecular vein communicates with reticulum tissue of the pulp. In the subendothelial circulatory canalicula of the splenic trabecular vein there can be observed emigrating picture of various leucocytes of the vein passing this subendothelium (chemotaxisis) and these cells emigrate and accumulate outside the splenic trabecula (intrasplenic cell recurrence). Arterial blood circulates in these subendothelial canaliculae and these canaliculae are not lymph canaliculae as demonstrated by JAGER and ROSSLE. Many leucocytes flow back into the pulp outside the trabecula through this circulatory system. Also in the peritrabecular pulp a new formation of collagen fibers and a considerable number of plasma cells can be observed in various infective spleens, and splenic trabecular area is the regenerating center and reactive center in the spleen, just as lymph follicle in the spleen.

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# THE SUBENDOTHELIAL CIRCULATORY SYSTEM IN THE SPLENIC TRABECULAR VEIN AND THE INTRA-SPLENIC CELL RECURRENCE

Tetsuo KIMOTO

*Department of Pathology, Okayama University Medical School, Okayama*
*(Director. Prof. Satimaru Seno)*

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Since the BANCROFT's[1] finding of the spleen as the reservoir of blood, the structure and the function of the sinuses and the arteries, which reach the sinuses after circulating the lymph follicle and pulp, have been well established. But concerning the trabecular vein in the spleen, only a few works have been reported and it has been generally accepted that the veins are only the vessels to carry out the blood from the sinus, as in the case of general vein.

Among the works of splenic vein MALLORY[2], OPPENHEIMER[3] and LUBARSCH[4] have described of the splenic veins which contain frequently a number of polynuclear leucocytes. In 1943 TANABE and the author[6.7.8] also met with the same change as described by MALLORY and others during the histological observations of the materials from the patients of leucopenia, who had been exposed to the atomic bomb at Hiroshima. In these cases a mass of neutrophils were found to be situated densely on the vessel wall forming a thick cell layer just inside the venous wall. At first the author speculated about that this change might appear especially marked in the cases being exposed to atomic bomb. But checking carefully a number of autopsy cases, the similar change in the splenic vein has been found in various infective diseases independently from the patient's history of being exposed to atomic bomb. Observations on a human spleen treated with the injection of India ink from splenic artery at autopsy revealed that the injected ink appears first in the subendothelial space of splenic veins where a mass of leucocytes are found connected to the arterial circulatory system and the leucocytes found in this area may be on the way back to the pulp, where some inflammatory changes are proceeding. Further observation on autopsy materials reconfirmed this fact. In this paper the facts supporting the view that in spleen the veins have a system to recurrent leucocytes into the pulp are presented.

## MATERIALS AND METHODS

The 297 spleens of autopsy cases including those from the corpses which

had been exposed to atomic bomb and the cases of typhoid fever, acute miliary tuberculosis and leukemic disease of various sorts served as materials for histologic observations (recurrence fever, 11; typhoid fever, 5; mycosis fungoides, 1; acute peritonitis, 2; pyothorax, 2; acute suppurative leptmeningitis, 2; tuberculosis, 42; leukemia, 20; phosphorous poisoning, 1; pneumonia, 4; liver abscess, 2; diphtheria, 1; and Banti's disease, 4; etc.). Tissue blocks 1 cu. cm. in size were fixed in 10% formalin, Orth or Susa fixative solution. In some cases the fixation was carried out by infusing the warm fixative solution (about 20°C) into the splenic artery at autopsy so that the fixation may be completed within a short period and the artefact by fixation may be minimized. In some cases about 15 cc of Ringer solution or physiological saline solution admixed with India ink, about 10 per cent was infused from the splenic artery prior to fixing the tissue block for the purpose to trace the circulatory system in detail. All the fixed tissues were dehydrated through a series of ethanol and embedded in paraffin or celloidine. Serial sections were prepared to study the architecture of vessels. Staining were made with hematoxylin eosin, Mallory, Weigert elastic fiber staining and BIELSGHOWSKY silver staining.

## OBSERVATIONS

In acute infectious diseases, especially typhoid fever, the earliest change in the spleen is an acute congestion or engorgement. And an increased amount of blood is brought under the influence of the phagocytes of the organ, which soon show proliferative and increased functional activity. Red corpuscles are often taken up by macrophages, with the formation of hemosiderin as the ultimate result phagocytosis of polymorpho-nucleus leucocytes also may occur, though it is not so common as in the sinuses of lymph nodes. In tuberculous involvement, especilally in acute miliary tuberculosis the tubercles are marked numerous in the spleen containing caseous masses, which are sometimes associated with infarcts. Frequently the wall of the trabecular vein and peritrabecular tissues are not affected by these lesion.

In leukemia the condition of the spleen is usualy the same as in lymphatic leukemia. Large hyperplasia of the lymphatic nodule and infiltration of leukemic cells can be seen in pulp.

The materials of spleens exposed to atomic bomb are 17 cases including those donated by Prof. TAMAGAWA of Hiroshima University. According to the number of days elapsed after the onset of symptoms they are divided into 3 groups: group I, 10 cases, (24 to 28 days after the onset); group II, 3 cases, (37 to 38 days after the onset) and group III, 4 cases, (50 to 63 days after the on set). All of them presented a marked leucopenia probably induced by the neutron

radiation of the atomic bomb explosion.

Histologically, the most noticeable and severe changes in the spleen are atrophy and disappearance of lymph follicles with a marked decrease in the lymphocyte number. Actually most of all lymph follicles present a network appearance due to residual reticulum tissue with a loss of lymphocytes by their emigration or degeneration and some follicles appear very small in size.

In the pulp a marked hyperèmia and some hemorrhagic areas are not infrequently encountered. The tissue structure are further modified by the proliferation of pulp cells, which are generally swollen and the infiltration with plasma cells and monocytes with or without erythrophages and scattered with some multinucleated giant cells, probably megakaryocytes.

The pulp appears generally oedematous with the swelling of the reticulum cells and in a few cases a marked deposition of hemosiderin was encountered. Necrotic area is observed more or less in all the cases, and in one case necrosis is extremely extensive and pronounced. These must be the result of thrombosis in small arteries. Their wall shows fibrinoid swelling with a distorted structure. Small arteries show a deposit of hyaline substance.

The most outstanding change is found in the vein. The presence of the circulatory system in the subendothelium of the splenic trabecular vein, that carries arterial blood, is a new fact that has been verified by us (Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11). Namely, in observation of the infective spleen injected with India ink and the ink appears rapidly in the subendothelial canaliculae of the splenic trabecular vein and in the pulp around the trabecular vein where there are cell accumulations, while on the contrary, in the pulp in the vicinity of this region no India ink can at all be seen (Fig. 3). It is evident that the subendothelial canaliculae of the splenic trabecular vein directly receive the arterial circulation, and thus from these it has been possible to conclude that these specific canaliculae are not lymph pathways as claimed by LUBARSCH[4] but they are one of the specific arterial circulatory system by which the arterial blood circulates through this canaliula and pours into the exterior pulp.

In the spleens exposed to atomic bomb, that demonstrates the subendothelial circulatory canaliculae of the splenic trabecular vein just in as high percentage as in the infective spleens, there can be observed emigration of various leucocytes of the vein passing through this subendothelium, and these cells emigrate and accumulate outside the splenic trabeculae (Figs. 2, 5, 6, 7, 8, 9 and 10).

The cell groups that accumulate in the subendothelial canaliculae, intratrabecula as well as outside the trabecula, are composed of plasma cells, monocytes, histiocytes and lymphoid cells (Figs. 2, 9 and 10). Also in leukemic spleens this feature has been observed (Fig. 11). And these cell groups differ from those of pulp that show extensive necrosis and these areas are not affected of such

where there are accumulations of cells outside the splenic trabecula, and these cells are connected with one another in a reticular formation by their cellular projections. In contrast to the destruction of reticulum fibers or collagen fibers observable in the pulp far away from the splenic trabecula, the regeneration of the collagen fibers composed of young fibers is marked in the peritrabecular area, and here regeneration of the pulp worthy of attention can be recognized (Figs. 14, 15 and 16).

## DISCUSSION

In the available literature concerning the structures of the splenic tissues the studies have been mainly carried on the blood vessel architecture, especially on the arterial circulatory system. Namely, as is well known, on the question how the peripheral arterial capillaries are connected with the pulp, there are two contentions, one contending that arterial capillaries are closed while the other upholding a view that arterial capillaries are open in the pulp. Concerning the peripheral artery, ONO[8] and IMAI[9] observed on the margin of lymph follicles in the human fetal spleen and the cat spleen. NAKAGAWA[10] also studied the peripheral arterial capillary system and he advocated "splenon" as a unit including the lymph system. However, all these observations are limited on the arterial system, and the findings on the histological structures of the splenic trabecular vein are very simple. Of course, there are some studies on the histological structures of the splenic trabecular vein by WEIDENREICH, MANGULI-KUDRJAVTZEMA, MOLLIER and MÖLLENDORF[11], but they merely mention this blood vessel to be covered by a single layer of endothel cells, which is negative to vital staining and the sublayer to be constituted of a coarse connective tissue. There are a few investigators who point out the structures of the wall of the splenic trabecular vein and cells appearing in this subendothelial canaliculae of the trabecular vein in particular. (SNOOK *et al.*[13]). LUBARSCH, in his observations on the the cells appearing in lines on the subendothelial canaliculae of the trabecular vein in lymphocytic leukemia, designated this canalicula as lymph capillary (Kapilläre Lymphräume).

In the spleen of the patient exposed to atomic bomb as well as in the infective spleen and leukemic spleen sometimes characteristic endothelium of the trabecular vein can be observed (Figs. 3 and 11) and these canaliculae in the trabecular vein communicate themselves with reticular tissue of the pulp. Sometimes this canalicula is observable in the trabecular tissue (Fig. 4).

The communication with the lymph vessels of the spleen as mentioned by JÄGER[12] is not revealed. By injecting India ink into the splenic artery as mentioned, the author has recognized a direct communication between these canali-

culae and arterial capillaries, and concluded that these canaliculae to be arterial blood vessls.

At this point an attention must be called to the fact that in the spleen exposed to atomic bomb there can be recognized "cell recurrence", particularly histiocytes and leucocytes, that once flowed out of the splenic vein flow back to the subendothelial canalicula, and that blood cells are emigrating out and are accumulating outside the trabecula. This mechanism is mainly chemotaxis of leucocytes. HAYMAKER[14], RÖSSLE[15], and CORONINI[16] have taken a notice of such cell groups in the subendothelium of the trabecular vein, but they have not reported about the relationship with arterial system.

Despite marked leucopenia in peripheral blood of the patients exposed to atomic bomb leucocytes are markedly accumulated in the splenic sinuses and around the splenic trabecular vein (Figs. 12 and 13), and if such venous blood cells were all circulated out of the spleen, many of the same leucocytes should be observable in the portal vein or in the liver. However, on the contrary, in the liver few leucocytes and histiocytes were observable. Namely, in this disease in spite of a marked decrease in the number of leucocytes in peripheral blood, it is in a way a strange phenomenon to see the localized leukocytosis. However, it is believed that most of the leucocytes, by cell recurrence into the spleen as mentioned above, play a significant role in the regeneration and recovery of the functions of the pulp. Also the splenic trabecular areas are the regenerating center and reactive center in the spleen. Frequently a considerable number of plasma cells and a new formation of fine fibers are observable in various infective spleens.

## CONCLUSION

In the spleen of patient exposed to atomic bomb as well as in the infective spleen and leukemic spleen sometimes characteristic endothelium of the trabecular vein can be observed and this canalicula in the trabecular vein communicates with reticulum tissue of the pulp. In the subendothelial circulatory canalicula of the splenic trabecular vein there can be observed emigrating picture of various leucocytes of the vein passing this subendothelium (chemotaxisis) and these cells emigrate and accumulate outside the splenic trabecula (intrasplenic cell recurrence). Arterial blood circulates in these subendothelial canaliculae and these canaliculae are not lymph canaliculae as demonstrated by JÄGER and RÖSSLE. Many leucocytes flow back into the pulp outside the trabecula through this circulatory system. Also in the peritrabecular pulp a new formation of collagen fibers and a considerable number of plasma cells can be observed in various infective spleens, and splenic trabecular area is the regenerating center and reactive center in the spleen, just as lymph follicle in the spleen.

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EXPLANATION FOR PHOTOS

Fig. 1. Lymphocapillary-like canalicula (S) in the splenic trabecular vein. T: Trabecula. V: Vein. Hematoxylin eosin staining.

Fig. 2. The accumulation of lymphoid cells and red blood cells, etc. are observable in the subendothelial circulatory system (S) and also their cells accumulate in the pulp of peritrabecula (P). Hematoxylin eosin staining.

Fig. 3. Splenic trabecular vein of typhoid fever. Injected ink to splenic artery appears first in the subendothelial space (S) of splenic veins (arrow ↙) where a mass of leucocytes are found. (arrow ↙) A: Splenic artery. (India ink). T: Trabecula. P: Pulp. V: Splenic vein. hematoxylin eosin staining.

Fig. 4. The canalicula in the trabecula associated with the subendthelial canalicula and its vein (V). Through this pathway the subendothelial canalicula associates with the pulp directly. (P). Bielschowsky silver staining.


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Explanation of Photos

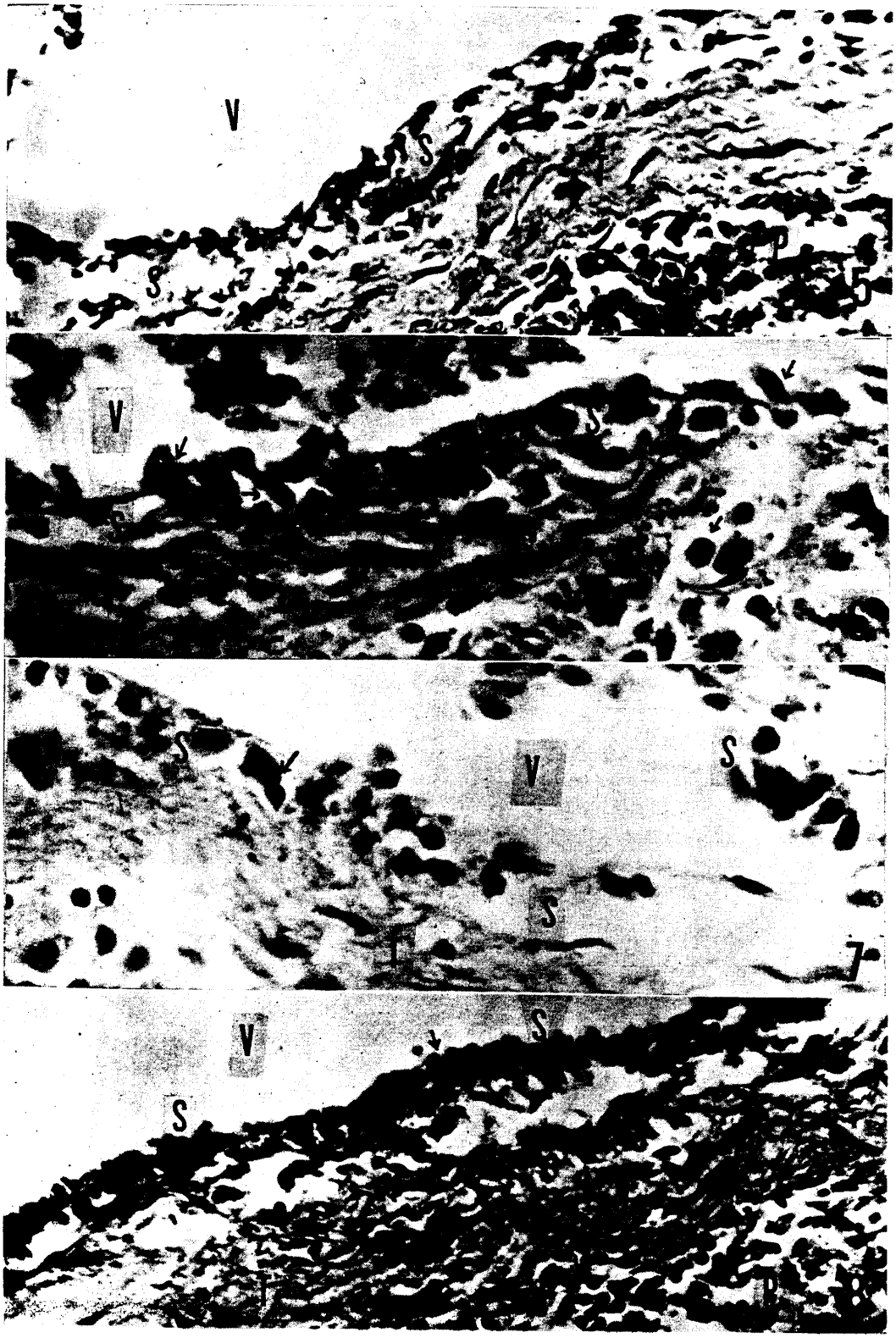
Cell groups in the subendothelial circulatory system.

Fig. 5. This canalicula is like to lymph capillary (Jäger and Lubarsch). A few lymphocytes and red blood cells are observable scattered in this canalicula and cell accumulation in the pulp around the trabecula (P) T: Trabecula V: Spenic vein. Hematoxylin eosin staining.

Fig. 6. Through the subendothelial circulatory system emigration of histiocytes from splenic vein to the pulp can be observed. (arrow ↓) V: Splenic vein T: Trabecula. Hematoxylin eosin staining.

Fig. 7. Accumulation of plasma cells in the subendothelial circulatory syatem (S). V: Splenic vein T: Trabecula. Hematoxylin eosin staining.

Fig. 8. Accumulation of lymphocytes in the subendothelial circulatory system. V: Splenic vein T: Trabecula P: Pulp (cell groups). Hematoxylin eosin staining.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Explanation of Photos

〔Cell Recurrence〕

Fig. 9. Cell recurrence from the subendothelial circulatory system (S) to the pulp (P). Accumulation of cells can be observed around the trabecula (P). Hematoxylin eosin staining.

Fig. 10. Cell recurrence (histiocytes) can be observed from the subendothelial circulatory system (S) to the pulp (P) through the trabecula canalicula (arrow ↑). T: Trabecula. V: Splenic vein. Hematoxylin eosin staining.

Fig. 11. Accumulation of cells in the subendothelial circulatory system in the case of leukemia (S). V; Trabecular vein. T: Trabecula.

Fig. 12. Many number of blood cells (mainly leucocytes) can be seen in the splenic veins (V) in spite of leukopenia in peripheral bloods. Hematoxylin eosin staining.


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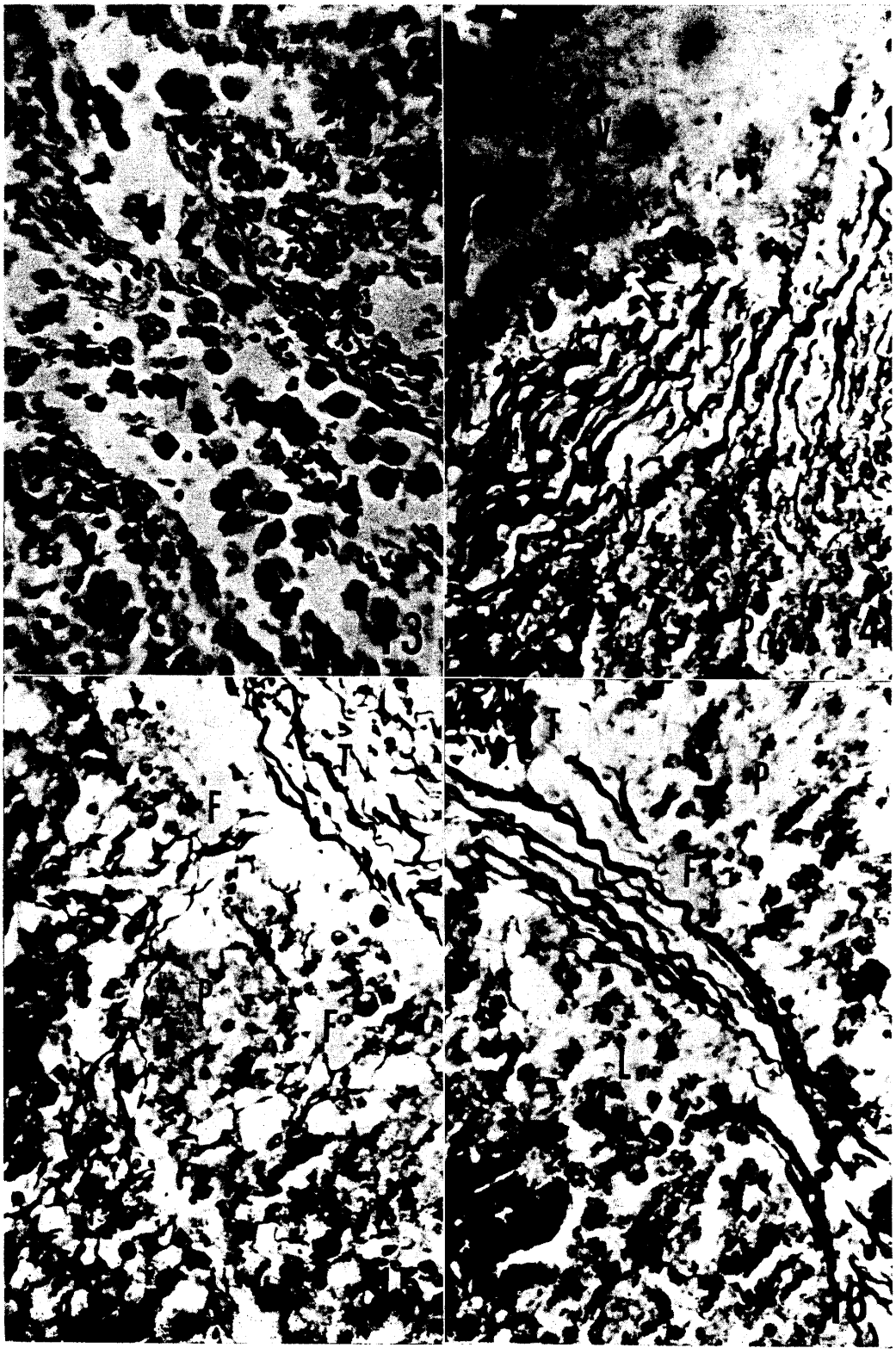
Explanation of Photos

〔Regeneration of the Pulp tissueis〕

Fig. 14. New formatien of collagen fiber around the trabecula. (F) S: Subendothelial canalicula P: Pulp. V: Splenic vein. Bielschowsky silver staining.

Fig. 15. New formation of collagen fiber (F) and regeneration of the pulp around the trabecula (P) in where cells recurrent and accumulate. T: Trabecula, Bielschowsky silver staining.

Fig. 16. Mantle of lymph follicle (L) is surrounded by the collagen fibers (F) formed newly from the trabecular tissue. T: Trabecula. P: Pulp. Bielschowsky silver staining.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